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**Sanborn et al.**

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(54) **WORK OF BREATHING DISPLAY FOR A VENTILATION SYSTEM**

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This patent is subject to a terminal disclaimer.

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***A61B 5/08*** (2006.01)

(52) **U.S. Cl.**
USPC ..... **600/538**; 600/529

(58) **Field of Classification Search**
USPC ..... 600/529–543
See application file for complete search history.

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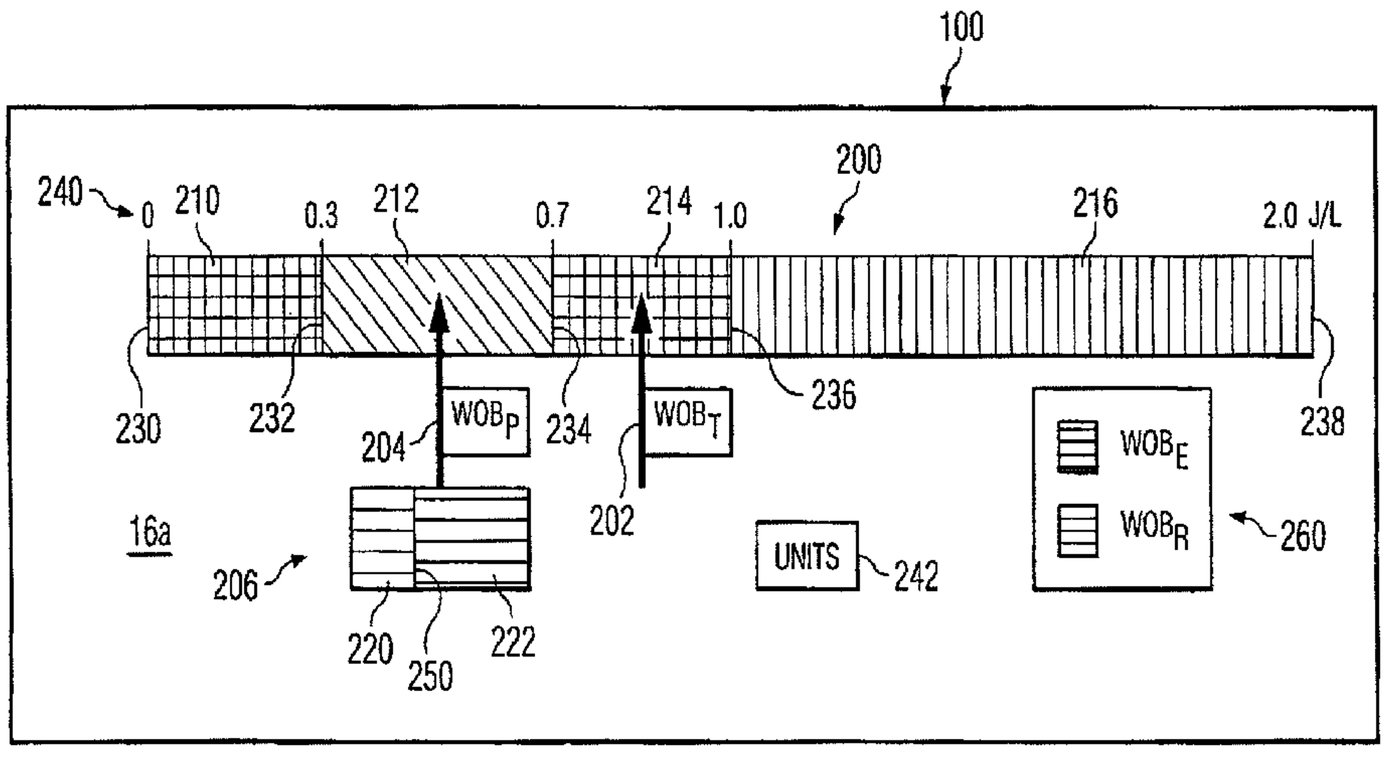
(57) **ABSTRACT**

A breathing support system is provided. The system may include a breathing support device configured to deliver gas to a patient and a display device associated with the breathing support device. The display device may be configured to display a graphic indicating one or more measures regarding the patient's work of breathing.

**21 Claims, 9 Drawing Sheets**



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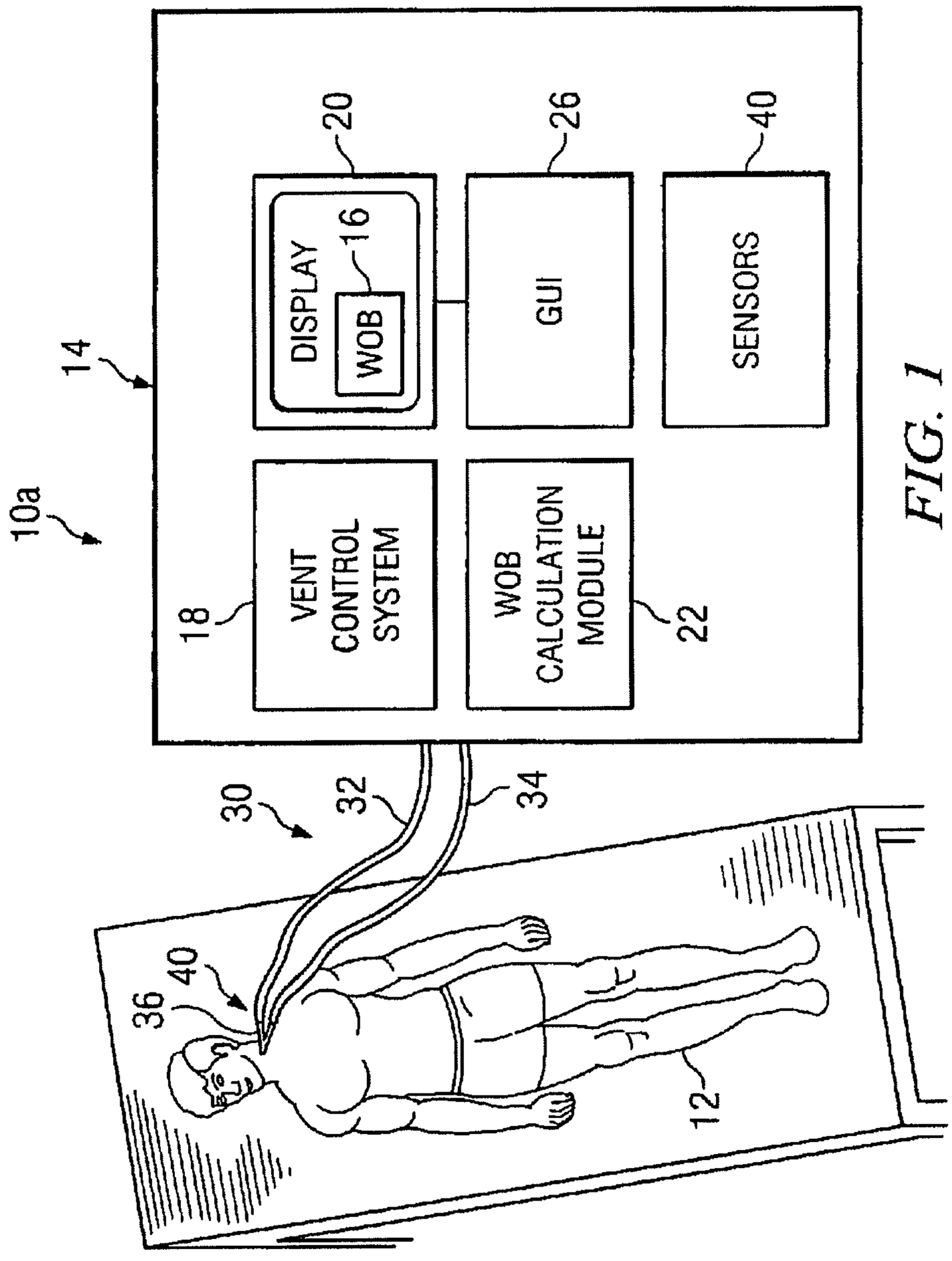
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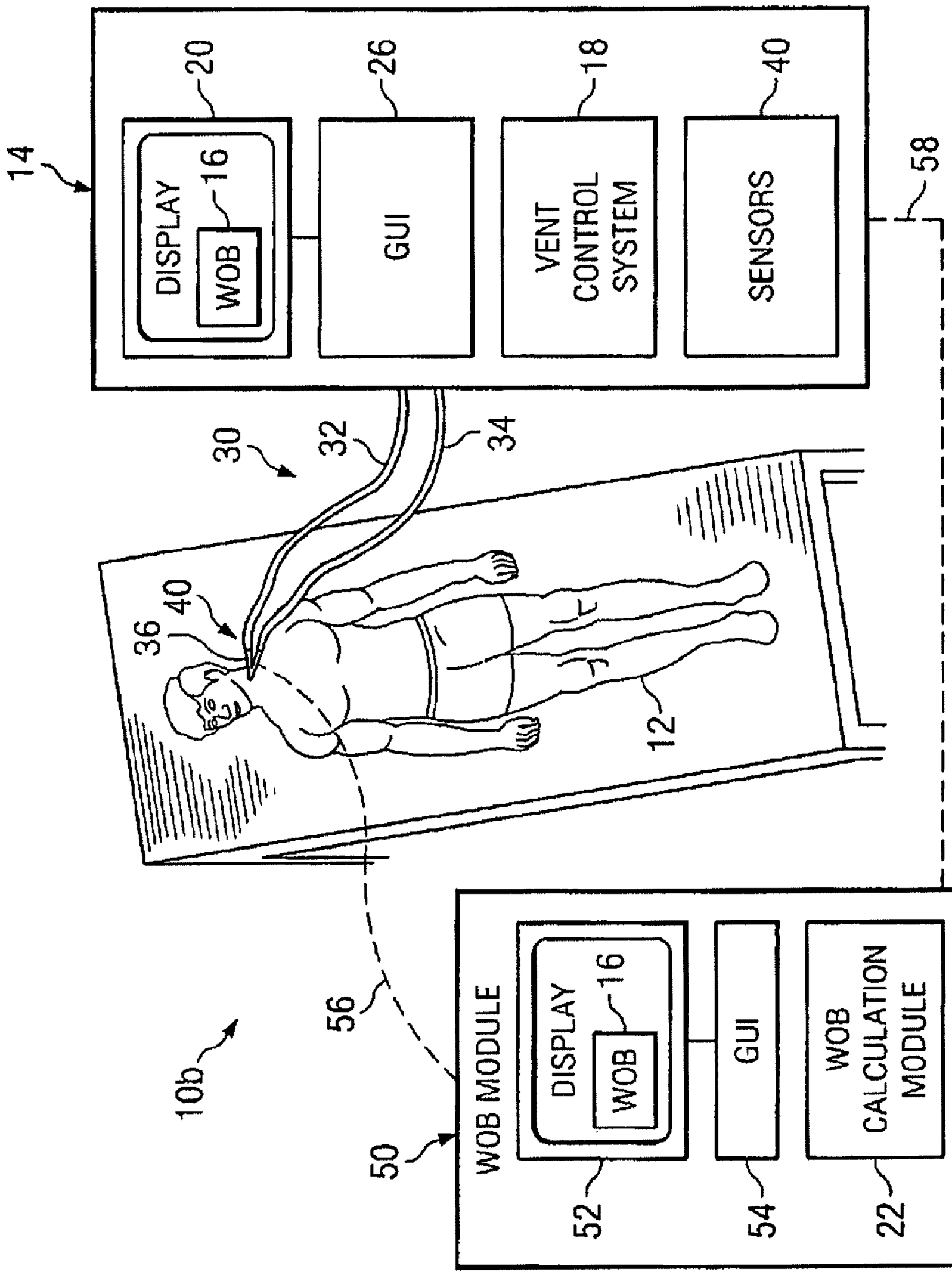
14
DISPLAY
WOB
16
GUI
SENSORS
20
26
40
18
VENT CONTROL SYSTEM
WOB CALCULATION MODULE
22
30
32
34
36
40
12

FIG. 1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GUI
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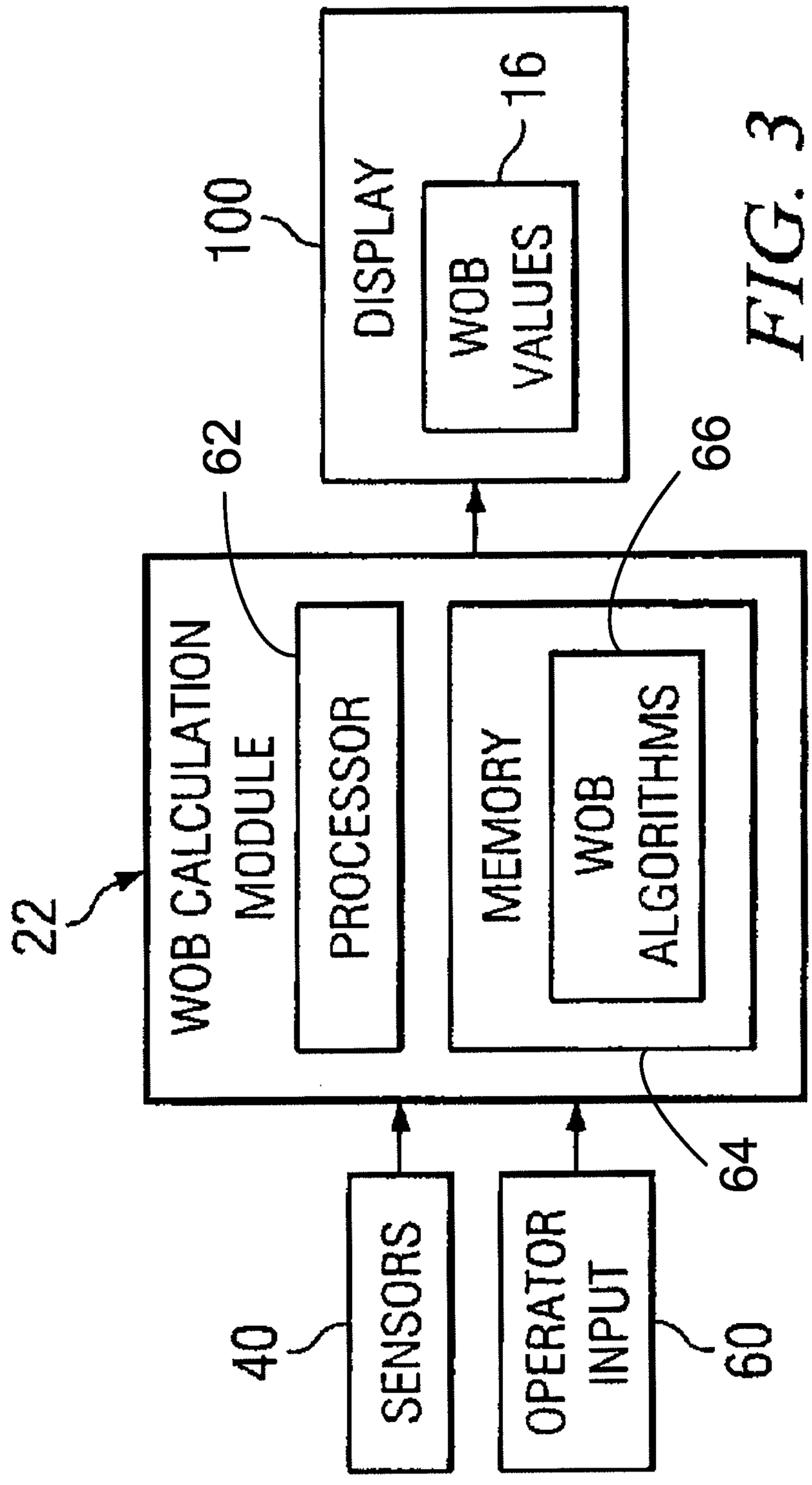
VENT CONTROL SYSTEM
18
SENSORS
40
58
30
32
34
36
40
12
10b
56
50
WOB MODULE
DISPLAY
16
WOB
GUI
WOB CALCULATION MODULE
52
54
22

FIG. 2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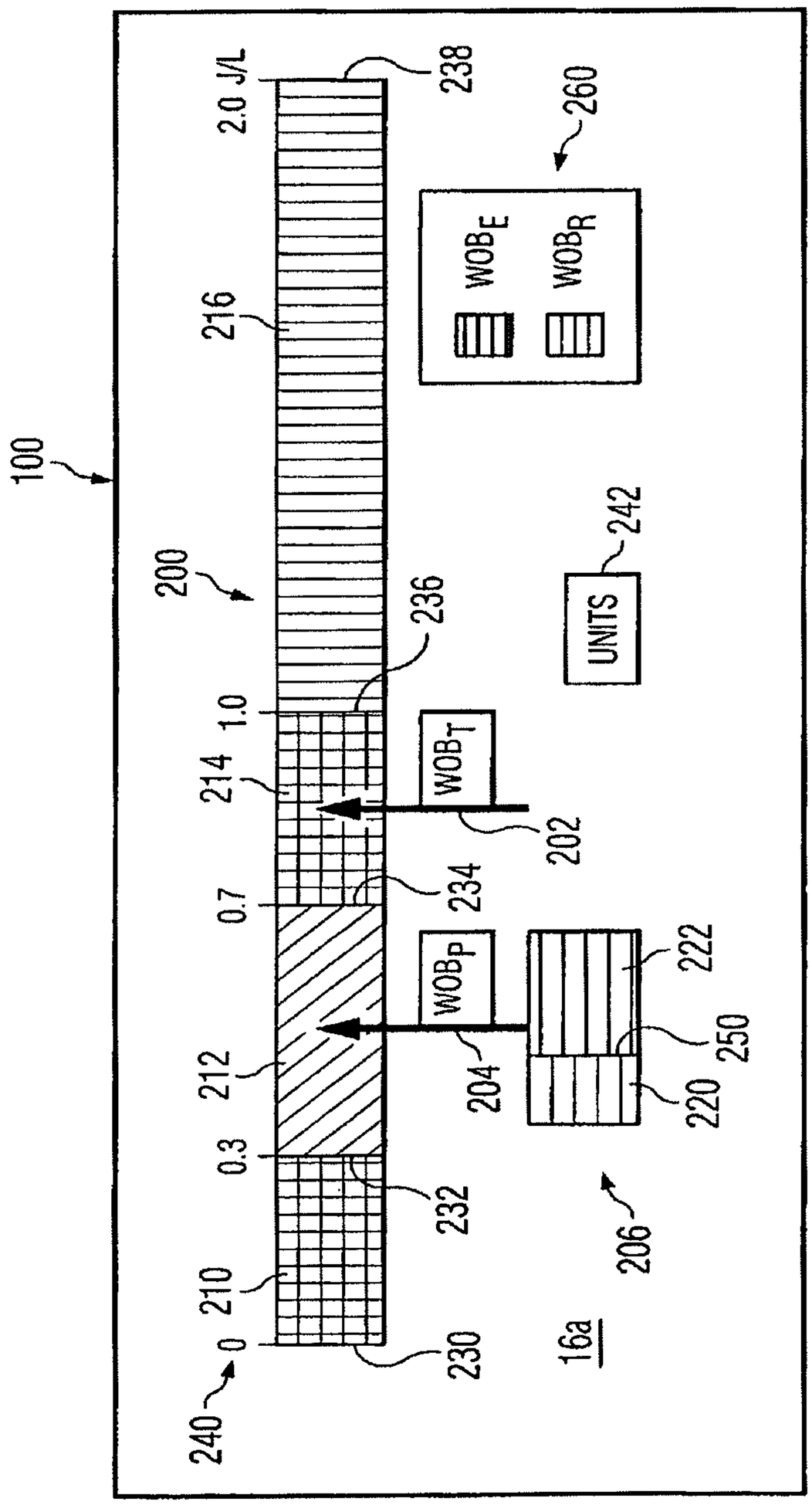
DISPLAY
16
WOB VALUES
62
66
22
WOB CALCULATION MODULE
PROCESSOR
MEMORY
WOB ALGORITHMS
64
40
SENSORS
OPERATOR INPUT
60

FIG. 3

FIG. 4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200
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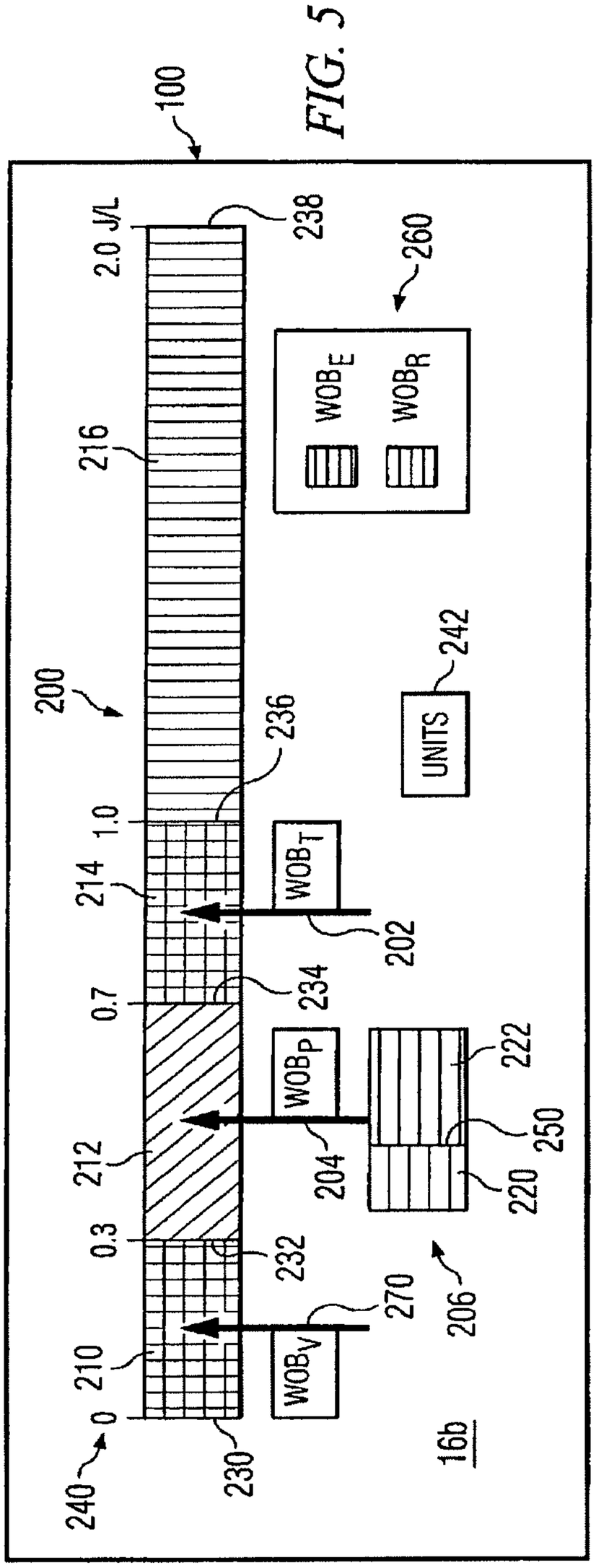
238
260
216
$WOB_E$
$WOB_R$
236
242
UNITS
1.0
214
$WOB_T$
202
234
0.7
$WOB_P$
222
212
204
250
220
0.3
232
210
206
0
230
240
16a

FIG. 5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202
0.7
234
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212
204
250
220
0.3
232
270
206
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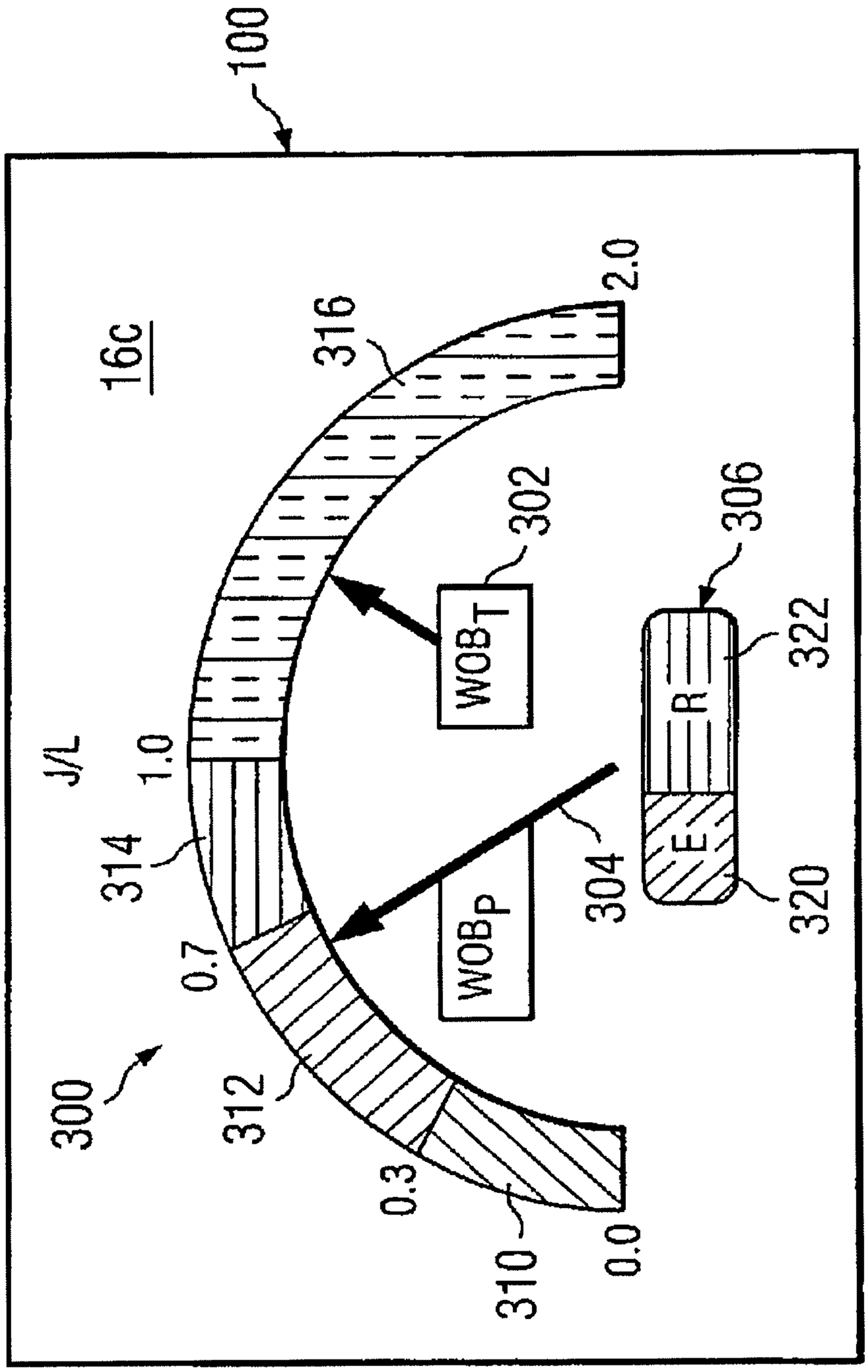
$WOB_V$
0
240
230
16b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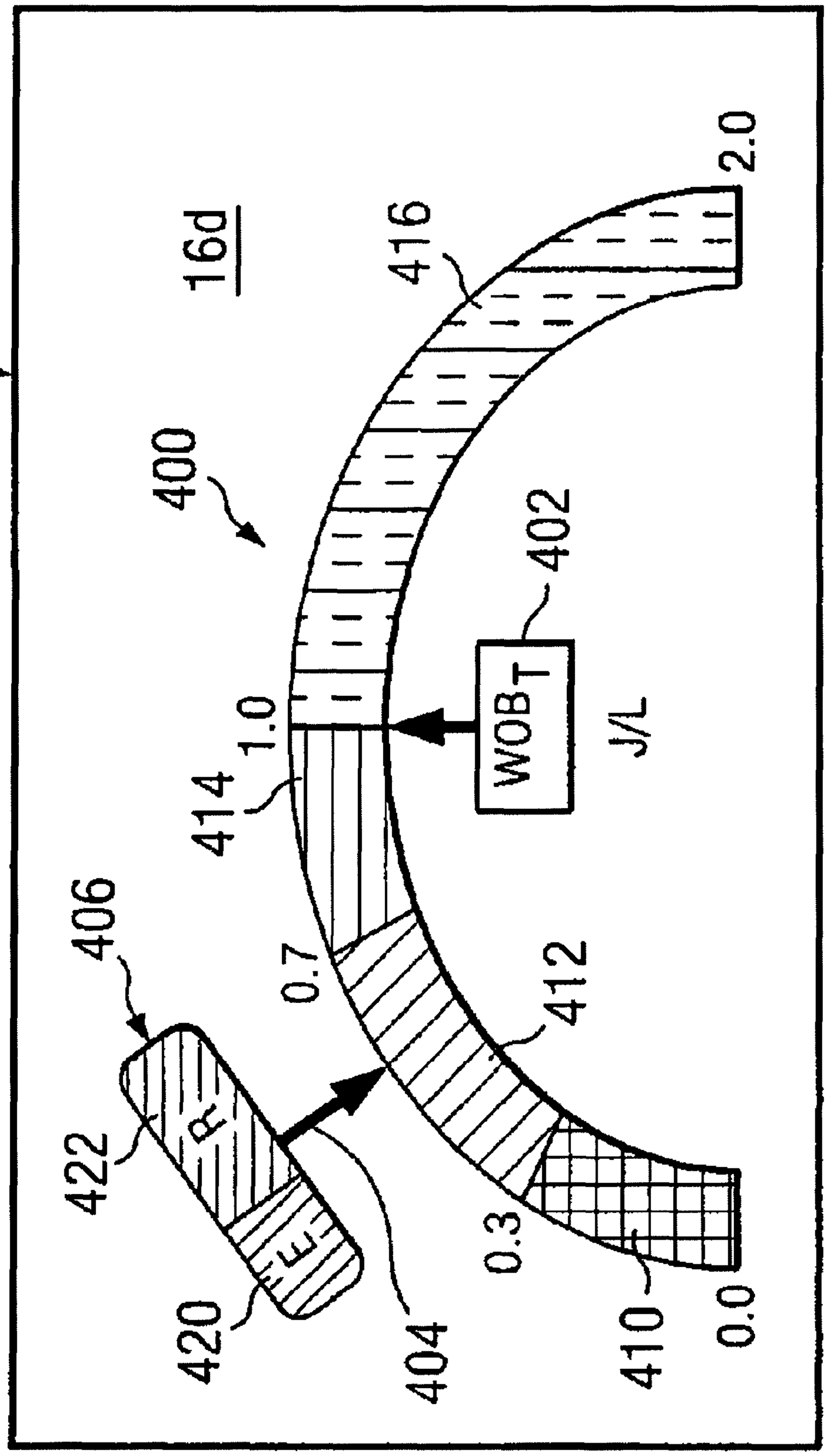
2.0
302
$WOB_T$
306
322
R
E
304
320
$WOB_P$
J/L
1.0
314
0.7
300
312
0.3
310
0.0

*FIG. 6*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400
402
WOBT
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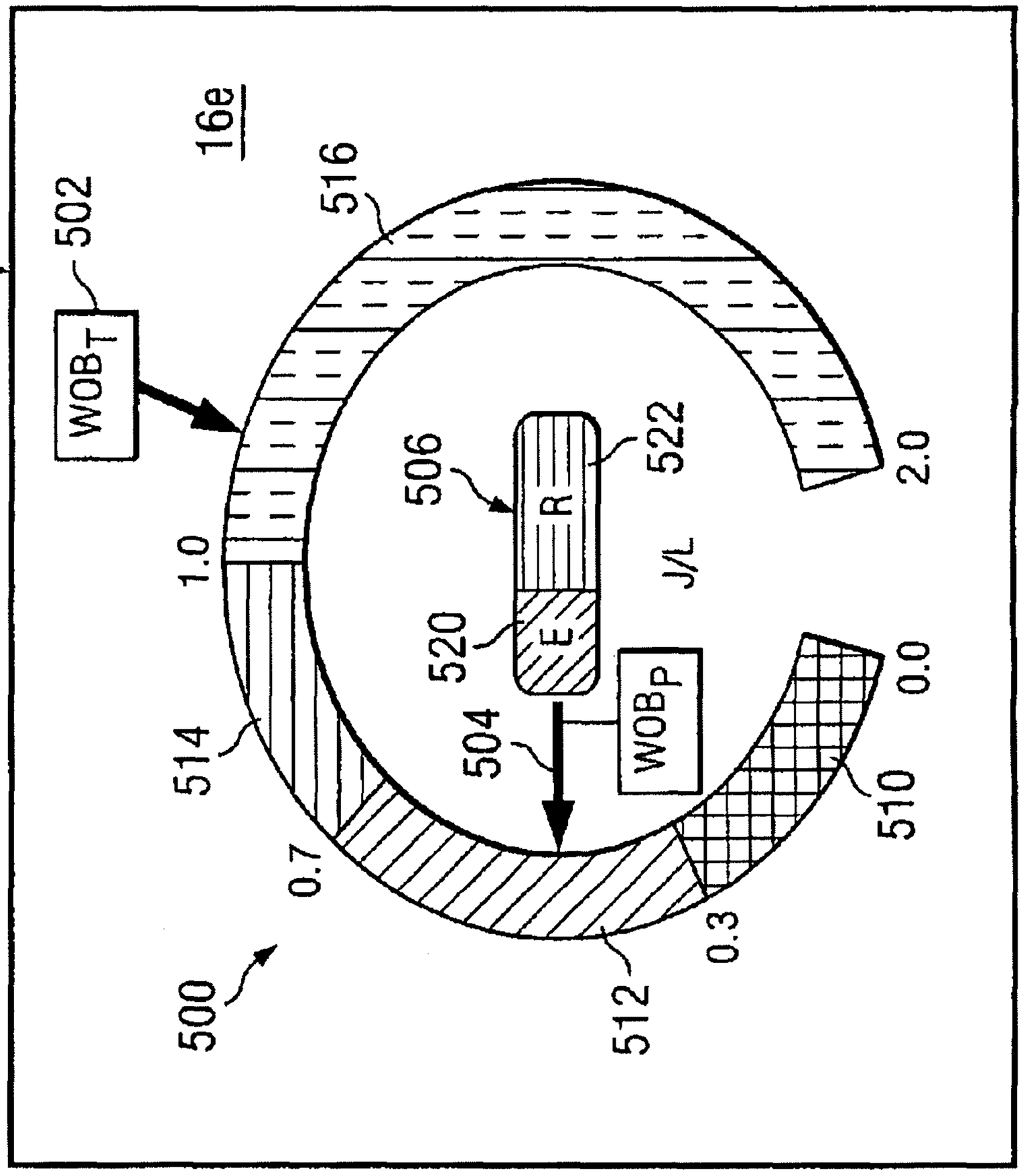
414
J/L
406
0.7
412
422
R
E
0.3
420
404
410
0.0

FIG. 7

FIG. 8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16e
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$WOB_T$
516
506
R
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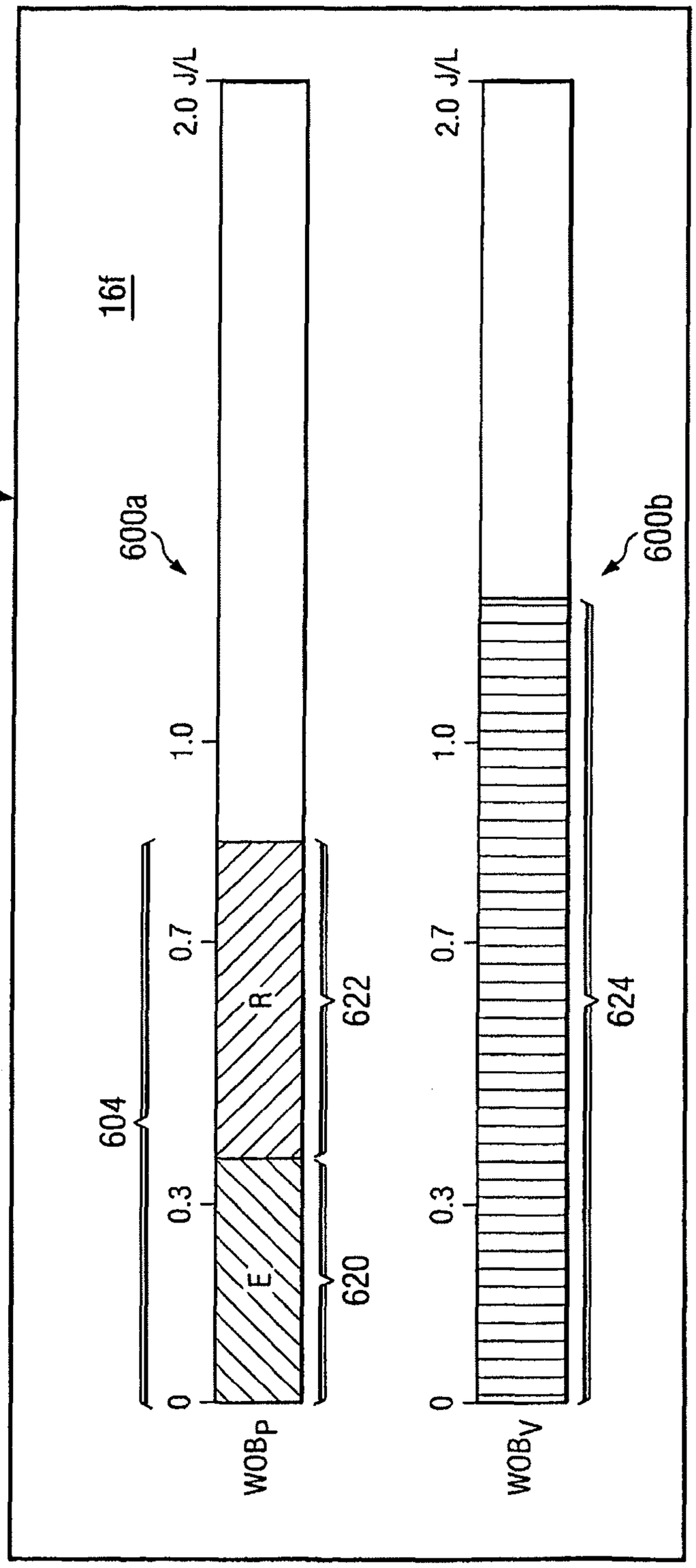
2.0
1.0
J/L
520
E
514
504
$WOB_P$
0.0
510
0.7
0.3
500
512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16f
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600a
600b
1.0
1.0
0.7
0.7
0.3
0.3
0
0
R
E
622
620
624
604
WOB_P
WOB_V

FIG. 9

# WORK OF BREATHING DISPLAY FOR A VENTILATION SYSTEM

## RELATED APPLICATIONS

This application is a continuation of prior application Ser. No. 11/408,457, filed Apr. 21, 2006, now U.S. Pat. No. 8,021,310, and entitled "WORK OF BREATHING DISPLAY FOR A VENTILATION SYSTEM," which application is hereby incorporated herein by reference.

## INTRODUCTION

One indication of a patient's condition during respiration support is the status of the patient's work of breathing (WOB). Work of breathing may be defined as the work associated with inflating the patient's lungs during a breathing cycle. During respiration support, a ventilator provides at least a portion of the total work of breathing for the patient. The total work of breathing ($WOB_{TOTAL}$) may generally be defined as the sum of the work of breathing provided by the patient ($WOB_{PATIENT}$) and the work of breathing support provided by the ventilator ($WOB_{VENTILATOR}$).

The work of breathing provided by the patient ($WOB_{PATIENT}$) may be approximated as the sum of two components: an elastic WOB component ($WOB_{PATIENT\text{-}ELASTIC}$) and a resistive WOB component ($WOB_{PATIENT\text{-}RESISTIVE}$). The elastic WOB component is generally defined as the work required to overcome the elastance of the patient's respiratory system, while the resistive component is generally defined as the work required to overcome the airway resistance of the patient's respiratory system.

Elastance may generally be defined in terms of the elastic properties of the lung and chest, or the forces associated with expanding the lung. In particular, the degree of stiffness of the lung-chest region may be referred to as the elastance of the respiratory system. The elastance of the respiratory system may also be discussed in terms of compliance, which may be defined as the inverse of elastance. Generally, the easier it is to stretch the lung-chest region.

Resistance forces, or the non-elastic forces at work in the breathing cycle, are the forces associated with moving air through a patient's airways. Lung resistance may be at least partially defined by a patient's physiological conditions. For example, patients suffering from asthma typically experience muscular constriction of the bronchi. Such patients may also experience swelling of the bronchial mucosa. The work required to achieve a particular amount of air flow through the breathing passageways generally increases in proportion to the severity of constriction. In some ventilation systems, flow and pressure sensors are used to compute estimates of the patient's resistance and compliance.

One or more WOB values, e.g., the total WOB, the patient's WOB (WOB PATIENT), the ventilator's WOB (WOB VENTILATOR), the elastic WOB component (WOB PATIENT-ELASTIC), and/or the resistive WOB component (WOB PATIENT-RESISTIVE) may be determined and/or monitored in various manners. For example, a patient's WOB may be determined from either measured or estimated values relating to the patient's respiratory physiology by applying direct or indirect approaches and following established algorithms. Measured values may be obtained more directly by invasive procedures, e.g., procedures that require the installation of an esophageal balloon. Such techniques are typically invasive and require specialized skill. Thus, outside of the research setting it may be undesirable to obtain WOB measures employing such invasive means.



In a pressure assisted ventilation (PAV) system, the patient's work of breathing ($WOB_{PATIENT}$), the elastic WOB component ($WOB_{PATIENT\text{-}ELASTIC}$), and/or the resistive WOB component ($WOB_{PATIENT\text{-}RESISTIVE}$) may be estimated by inputting measurements from various sensors into the breathing algorithms. In PAV ventilation, the patient is supplied with continuous pressure assistance throughout an inspiratory effort and in direct proportion to the moment-to-moment inspiratory effort. Typically, none of the instantaneous inspiratory pressure, the instantaneous flow, or the resulting volume are set by the caregiver. Because the PAV breathing algorithm harmoniously links the ventilator to the patient, the patient effectively "drives" the ventilator. By appropriately setting the value of the proportionality (% support) control, the caregiver may effectively partition the total WOB between the patient ($WOB_{PATIENT}$) and the ventilator ($WOB_{VENTILATOR}$).

The values of the patient's lung-chest compliance and lung resistance may be continuously estimated and inserted into the PAV breathing algorithm in order for the algorithm to function properly. These estimates may be made automatically by the ventilator and fed back to the breathing algorithm as perhaps better fits the needs of the patient in intensive care, whereas manual techniques may be used to estimate the values for more stable patients, e.g., in a home setting.

## WORK OF BREATHING DISPLAY FOR A VENTILATION SYSTEM

In accordance with the present disclosure, systems and methods for monitoring and/or displaying one or more work of breathing measures are provided.

According to one embodiment, a breathing support system is provided. The system may include a breathing support device configured to deliver gas to a patient, a software-generated work of breathing graphic indicating one or more work of breathing measures regarding the patient's breathing, and a display device associated with the breathing support device, the display device configured to display the software-generated graphic. The software-generated graphic includes a scale and one or more work of breathing indicators that move relative to the scale.

According to one embodiment, a breathing support system is provided. The system may include a breathing support device configured to deliver gas to a patient, a software-generated work of breathing graphic indicating one or more work of breathing measures regarding the patient's breathing, and a display device associated with the breathing support device, the display device configured to display the software-generated graphic. The software-generated graphic includes an elastic-resistive work of breathing graphic including a first portion and a second portion, the first portion indicating a measure of an elastic work of breathing component and the second portion indicating a measure of a resistive work of breathing component. The relative sizes of the first and second portions of the elastic-resistive work of breathing graphic dynamically adjust on a bar to indicate the measure of the elastic work of breathing component relative to the measure of the resistive work of breathing component.

These and various other features as well as advantages will be apparent from a reading of the following detailed description and a review of the associated drawings. Additional features are set forth in the description that follows and, in part, will be apparent from the description, or may be learned by practice of the described embodiments. The benefits and features will be realized and attained by the structure particularly

pointed out in the written description and claims hereof as well as the appended drawings.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the claimed invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The following drawing figures, which form a part of this application, are illustrative of embodiments systems and methods described below and are not meant to limit the scope of the invention in any manner, which scope shall be based on the claims appended hereto.

FIG. **1** illustrates a ventilation system for providing ventilation support to a patient, including a ventilator configured to display a work of breathing graphic, according to one embodiment of the disclosure.

FIG. **2** illustrates a ventilation system for providing ventilation support to a patient, including a ventilator and a separate module for displaying a work of breathing graphic, according to one embodiment of the disclosure.

FIG. **3** is a block diagram illustrating an example system for determining and displaying work of breathing measures, according to some embodiments.

FIG. **4** illustrates a first example graphic work of breathing graphic, according to one embodiment of the disclosure.

FIG. **5** illustrates a second example graphic work of breathing graphic, according to one embodiment of the disclosure.

FIG. **6** illustrates a third example graphic work of breathing graphic, according to another embodiment of the disclosure.

FIG. **7** illustrates a fourth example graphic work of breathing graphic, according to another embodiment of the disclosure.

FIG. **8** illustrates a fifth example graphic work of breathing graphic, according to another embodiment of the disclosure.

FIG. **9** illustrates a sixth example graphic work of breathing graphic, according to another embodiment of the disclosure.

## DETAILED DESCRIPTION

Selected embodiments of the disclosure may be understood by reference, in part, to FIGS. **1-9**, wherein like numbers refer to same and like parts.

In general, the present disclosure describes generating and/or displaying a work of breathing graphic (WOB graphic) for use with a ventilator or other breath delivery or breathing support system that may provide caregivers with various information concerning work of breathing through an easily understood graphical display. The WOB graphic may be used, e.g., for monitoring and/or adjusting the amount of work of breathing contributed by the patient and/or the amount contributed by the ventilator. For example, the display may allow a caregiver to monitor a patient's work of breathing in real time or substantially in real time. A caregiver may use such information for various purposes, such as, for example, to ensure that the patient's work of breathing is within a safe or desirable range and/or to determine whether and/or how to adjust one or more ventilator settings (e.g., to increase or decrease respiratory support to the patient).

In some embodiments, the WOB graphic may depict (graphically, numerically, or otherwise) the effect that changes in one or more ventilator settings have on the work of breathing being contributed by a patient, e.g., in order to determine whether or not such adjustments are causing a patient to work at a level above, within, or below an acceptable or desired range of work. The WOB graphic may be user-friendly such that caregivers of various degrees of technical sophistication may understand or interpret the display and/or be able to utilize the display for implementing or managing a respiration support strategy. Additionally, the WOB graphic may be used in conjunction with traditional ventilation systems and applications, e.g., pressure assisted ventilation (PAV) applications.

The WOB graphic may be displayed via any of a variety of media. For example, in some embodiments, the WOB graphic may be displayed by a ventilator or a ventilator control system. In other embodiments, the WOB graphic may be displayed on a separate display device (e.g., separate from a ventilator). In particular embodiments, the WOB graphic may be displayed in association with a ventilation control system for administering a respiration support strategy. In such embodiments, a ventilator may be connected to a graphic user interface having a digital processor, a display screen, and/or one or more user inputs, or the ventilator may itself include a graphic user interface. These components may cooperate to assist a caregiver in setting up and/or adjusting the work of breathing being provided by a patient and/or the work of breathing being provided by the ventilator.

In some embodiments, the WOB graphic may indicate the total work of breathing ($WOB_{TOTAL}$), the patient's work of breathing ($WOB_{PATIENT}$) (neither of which, one of which, or both of which advance or retreat along a scale) and/or the components of the patient's WOB—an elastic WOB component ($WOB_{PATIENT\text{-}ELASTIC}$) and a resistive WOB component ($WOB_{PATIENT\text{-}RESISTIVE}$). For example, the WOB graphic may include a $WOB_{TOTAL}$ graphic or indicator that indicates the total work of breathing, a $WOB_{PATIENT}$ graphic or indicator that indicates the patient's work of breathing, and an elastic-resistive WOB graphic that indicates a measure of the elastic WOB component ($WOB_{PATIENT\text{-}ELASTIC}$) relative to a measure of the resistive WOB component ($WOB_{PATIENT\text{-}RESISTIVE}$). As another example, the WOB graphic may include a $WOB_{TOTAL}$ graphic or indicator that indicates the total work of breathing, a $WOB_{PATIENT}$ graphic or indicator that indicates the patient's work of breathing, an elastic WOB graphic that indicates a measure of the elastic WOB component ($WOB_{PATIENT\text{-}ELASTIC}$), and a resistive WOB graphic that indicates a measure of the resistive WOB component ($WOB_{PATIENT\text{-}RESISTIVE}$). In other embodiments, one or more additional and/or other components of a total work of breathing measure may be displayed, e.g., the ventilator work of breathing ($WOB_{VENTILATOR}$).

In some embodiments, the WOB graphic may include a scale having any suitable shape and configuration (e.g., a linear scale, a circular or semicircular scale, or an elliptical scale) and one or more indicators that move relative to the scale to indicate one or more work of breathing parameters. For example, the WOB graphic may include a first indicator that moves relative to the scale to represent a measure of $WOB_{TOTAL}$, and a second indicator that moves relative to the scale to represent a measure of $WOB_{PATIENT}$. The scale may be divided into sectors that generally correspond to different work of breathing levels. The sectors may be visibly discernable from each other (or at least from immediately adjacent sectors). For example, the sectors may be color-coded or distinctively shaded.

An elastic-resistive WOB graphic may be divided into a first portion and a second portion, the first portion indicating the elastic WOB component ($WOB_{PATIENT\text{-}ELASTIC}$) and the second portion indicating the resistive WOB component ($WOB_{PATIENT\text{-}RESISTIVE}$). The relative sizes of the first and second portions of the elastic-resistive WOB graphic may

dynamically adjust to indicate the measure of the elastic WOB component relative to the measure of the resistive WOB component. In certain embodiments, the overall size of the elastic-resistive WOB graphic remains constant as the relative sizes of the first and second portions dynamically adjust.

FIGS. **1** and **2** illustrate two example embodiments of a ventilation system including a displayed WOB graphic. More particularly, FIG. **1** illustrates an example ventilation system including a ventilator configured to display a work of breathing graphic, while FIG. **2** illustrates an example ventilation system including a ventilator and a separate module for displaying a work of breathing graphic.

Referring to FIG. **1**, a ventilation system **10***a* for providing breathing assistance to a patient **12** may include a ventilator **14** configured to display a WOB graphic **16** and one or more devices for connecting ventilator **14** to patient **12**. As used throughout this document, the term "ventilator" may refer to any device, apparatus, or system for delivering breathing gas to a patient, e.g., a ventilator, a respirator, a CPAP device, or a BiPAP device. The term "patient" may refer to any person who is receiving breathing support from a ventilation system, regardless of the medical status, official patient status, physical location, or any other characteristic of the person. Thus, for example, patients may include persons under official medical care (e.g., hospital patients), persons not under official medical care, persons receiving care at a medical care facility, persons receiving home care, etc.

Ventilator **14** may include a ventilation control system **18**, a display device **20**, and a WOB calculation module **22**. Ventilation control system **18** may be operable to control the ventilation support provided by ventilator **14** based on various inputs, such as inputs received from an operator and/or data received from various sensors, as discussed below. Display device **20** may be fully or partially integrated with ventilator **14** and may comprise, e.g., a touch screen display or other visual display. Display device **20** may be configured to display various information regarding the ventilation of patient **12**, including WOB graphic **16** and/or other information regarding the ventilation of patient **12** (e.g., tidal volume, minute ventilation, and respiration rate). WOB graphic **16** may display one or more work of breathing measures in any suitable manner, e.g., graphically, numerically, or otherwise. WOB graphic **16** may be a full screen display or may occupy a portion of a display screen. For example, WOB graphic **16** may be located in a window or a portion of a display that includes other information regarding the ventilation of patient **12**.

Display device **20** may be part of or otherwise associated with, a graphic user interface **26**. In this embodiment, graphic user interface **26** may be configured to display WOB graphic **16** and/or other information via display device **20** and/or provide an interface for accepting input from human operators via display device **20** and/or other input devices (e.g., to set or modify ventilation settings, to access data, and/or to change or configure the display).

Patient **12** may be connected to ventilator **14** by a breathing circuit **30** that may include an inspiration conduit **32**, an exhalation conduit **34**, and/or a patient connection apparatus **36**. Patient connection apparatus **36** may include any device or devices configured to connect breathing circuit **30** to one or more breathing passageways of patient **12**. For example, patient connection apparatus **36** may include a patient connection tube directly connected to the patient's trachea, an artificial airway (e.g., an endotracheal tube or other device) inserted in the patient's trachea, and/or a mask or nasal pillows positioned over the patient's nose and/or mouth. In embodiments including a patient connection tube, the patient connection tube may include a Wye (or "Y") connector.

Ventilation system **10***a* may include one or more sensors **40** for sensing, detecting, and/or monitoring one or more parameters related to the ventilation of patient **12**, e.g., parameters regarding the ventilation provided by ventilator **14** and/or physiological parameters regarding patient **12**. For example, sensors **40** may include one or more devices for measuring various parameters of gas flowing into or out of patient **12** or ventilator **14**, e.g., the pressure, flow rate, flow volume, temperature, gas content, and/or humidity of such gas flow. Thus, sensors **40** may include, e.g., one or more pressure sensors, flow meters, transducers, and/or oxygen sensors. Sensors **40** may be located at one or more various locations in ventilation system **10** for monitoring the pressure and or flow of gasses flowing into and/or out of patient **12** and/or ventilator **14**. For example, one or more sensors **40** may be located in or proximate ventilator **14**, breathing circuit **30**, and/or patient connection apparatus **36**. For example, depending on the particular embodiment, one or more sensors **40** may be located within or proximate to ventilator **14**, inspiration conduit **32** and/or exhalation conduit **34** or breathing circuit **30**, an artificial airway, and/or a Wye connector.

As discussed above, ventilation control system **18** may be operable to control the ventilation support provided by ventilator **14** based on various input received from an operator (e.g., via graphic user interface **26** and/or other user interfaces on ventilator **14**) and/or data received from one or more sensors **40**. For example, ventilation control system **18** may regulate the pressure and/or flow of gas delivered to a patient based at least on data received from sensors **40**.

WOB calculation module **22** may be operable to calculate or otherwise determine one or more work of breathing measures based on various input data, including data collected by sensors **40**, as described in greater detail below with reference to FIG. **3**. Such work of breathing measures determined by WOB calculation module **22** may then be communicated to graphic user interface **26** for display via display device **20**.

According to the embodiment shown in FIG. **2**, a ventilation system **10***b* for providing breathing assistance to a patient **12** may include a ventilator **14**, one or more devices for connecting ventilator **14** to patient **12**, and a separate WOB module **50**. Ventilator **14** may include a ventilation control system **18** and a display screen **20**, such as discussed above regarding the embodiment shown in FIG. **1**. Ventilation control system **18** may be operable to control the ventilation support provided by ventilator **14** based on various inputs, such as inputs received from an operator and/or data received from various sensors, as discussed below. Display device **20** may be fully or partially integrated with ventilator **14** and may comprise, e.g., a touch screen display or other visual display. Display device **20** may be configured to display various information regarding the ventilation of patient **12**. Display device **20** may be part of or otherwise associated with, a graphic user interface **26**. In this embodiment, graphic user interface **26** may be configured to display various information via display device **20** and/or provide an interface for accepting input from human operators via display device **20** and/or other input devices (e.g., to set or modify ventilation settings, to access data, and/or to change or configure the display).

WOB module **50** may include a display device **52**, a WOB calculation module **22**, and any other suitable hardware or software for determining and/or displaying one or more WOB measures. For example, WOB module **50** may be configured to display a WOB graphic **16** via display device **52**, e.g., a touch screen display or other visual display. As discussed above, WOB graphic **16** may be a full screen display or may

occupy a portion of a display screen. In some embodiments, WOB module **50** may include a graphic user interface **54**, which may be operable to display WOB graphic **16** and/or other information via display device **52** and, in some embodiments, provide an interface for accepting input from human operators via display device **52** and/or other user input devices (e.g., to set or modify various settings, access data, and/or change or configure the display).

WOB calculation module **22** may be operable to calculate or otherwise determine one or more work of breathing measures based on various input data, including data collected by sensors **40**. WOB calculation module **22** may receive such input data from any suitable component of ventilation system **10***b*. For example, WOB module **50** may be communicatively coupled to one or more sensors **40** (e.g., sensors **40** located at or proximate to an artificial airway (e.g., an endotracheal tube or other device), a Wye connector, or breathing circuit **30**) such that WOB module **50** may receive data directly from such sensors **40**, e.g., as indicated by dashed line **56**. Alternatively, WOB module **50** may be communicatively coupled to ventilator **14** such that WOB module **50** may receive data from ventilator **14** (e.g., as indicated by dashed line **58**), which may include data received from various sensors **40** (which data may or may not be first processed or otherwise acted on by ventilator **14** and then communicated to WOB module **50**). WOB calculation module **22** may receive data from sensors **40** directly or indirectly in any other suitable manner. WOB calculation module **22** may then calculate or otherwise determine one or more work of breathing measures based on such data from sensors **40**, and communicate the determined work of breathing measures for display via display device **52**.

It should be understood that components of ventilation systems **10***a* and **10***b* may include any hardware, software, firmware or other components suitable for providing ventilation assistance to patient **12** and/or determining and displaying one or more work of breathing measures. For example, ventilator **14** may include various processors, memory devices, user inputs, status indicators, audio devices, and/or software or other logic for providing various ventilator functions.

FIG. **3** is a block diagram illustrating an example system for determining and displaying work of breathing measures, according to some embodiments. As discussed above, WOB calculation module **22** may be operable to calculate or otherwise determine one or more work of breathing measures based on various input data. Such input data may include data received from sensors **40** and/or data or settings input by an operator, indicated in FIG. **3** as operator input **60**. Such WOB measures may then be represented in a WOB graphic **16** displayed on any suitable display device **100**, e.g., display devices **20** or **52** discussed above with reference to FIGS. **1** and **2**. For example, WOB calculation module **22** may calculate measures for $WOB_{TOTAL}$, $WOB_{PATIENT}$, $WOB_{VENTILATOR}$, $WOB_{PATIENT\text{-}ELASTIC}$, and/or $WOB_{PATIENT\text{-}RESISTIVE}$. One, some, or all of these measures may then be displayed in a WOB graphic **16** in any suitable manner, e.g., using graphic and/or numeric representations.

WOB calculation module **22** may include a processor **62**, memory **64**, and any other suitable hardware or software. Memory **64** may store one or more WOB algorithms **66** and/or any other suitable software or logic that may be executable by processor **62** for calculating one or more work of breathing measures, e.g., as discussed below.

WOB calculation module **22** may use data collected by sensors **40** to calculate or otherwise determine work of breathing measures in any of a variety of manners. For example, in some embodiments in which a balloon is inserted in the patient's esophagus, sensors **40** may be used to monitor pressure and volume (flow*time) at the airway opening (e.g., at or proximate to a Wye connector). Such data may be communicated to WOB calculation module **22**, which may determine or calculate one or more WOB measures based on such received data.

Alternatively, WOB calculation module **22** may calculate estimated WOB measures based on data monitored entirely external to the patient, e.g., using WOB **66** algorithms that use data from sensors **40** as inputs. For example, in a pressure assisted ventilation (PAV) environment, WOB calculation module **22** may receive data from sensors **40** positioned in or proximate to ventilator **14** and calculate estimated WOB measures using such data as inputs for one or more suitable PAV algorithms. Example techniques for providing or generating PAV, which may lead to WOB calculations, are disclosed in U.S. Pat. No. 5,107,830, which is hereby incorporated by reference in its entirety. In addition, example techniques for determining or approximating resistance and/or elastance in a PAV environment, which may be used in calculating WOB values, are disclosed in U.S. Pat. No. 5,884,622 and U.S. Pat. No. 6,837,242, which are hereby incorporated by reference in their entirety.

Thus, in some embodiments, WOB calculation module **22** may include or use such techniques and/or other known techniques for calculating estimated WOB measures, which may then be displayed via WOB graphic **16**. It should be understood that WOB measures may be measured, estimated, or otherwise determined in any other suitable manner in both PAV and non-PAV environments.

Various example embodiments of WOB graphic **16** are illustrated in FIGS. **4-9**, as discussed in greater detail below. WOB graphic **16** may be displayed on any suitable display device **100**, e.g., display devices **20** or **52** discussed above with reference to FIGS. **1** and **2**. Although the present disclosure discusses the generation and/or display of a WOB graphic in connection with a ventilator, it should be understood that the disclosed WOB graphics may similarly be used in connection with other stand-alone systems or devices that calculate WOB measures.

WOB graphic **16** may comprise, e.g., a graphic on a general-purpose display screen or on a dedicated display or display device, and may be configured to provide a user-friendly display that represents a patient's work of breathing. However, display device **100** may additionally or alternatively be operable to visually represent patient data, alarm conditions, various charts, graphs, tables, and/or other such information as may be appropriate or useful to a caregiver in assessing a patient's respiratory or other vital functions. For example, the display of display device **100** may be divided into multiple sections, with one section displaying the WOB graphic **16** while one or more other sections display various other items such as ventilator parameters, patient data, etc. However, such information may alternatively be displayed in a non-sectored layout, e.g., intermingled or integrated with the WOB graphic **16**.

As discussed above, WOB graphic **16** may indicate the total work of breathing ($WOB_{TOTAL}$), the patient's work of breathing ($WOB_{PATIENT}$), and/or the components of the patient's WOB—an elastic WOB component ($WOB_{PATIENT\text{-}ELASTIC}$) and a resistive WOB component ($WOB_{PATIENT\text{-}RESISTIVE}$). In some embodiments, WOB graphic **16** may include a scale having any suitable shape or configuration (e.g., a linear scale, a circular or semicircular scale, or an elliptical scale) and one or more indicators that move relative to the scale to indicate one or more work of breathing parameters.

For example, WOB graphic **16** may include a $WOB_{TOTAL}$ indicator that moves relative to the scale to represent a measure of $WOB_{TOTAL}$, and a $WOB_{PATIENT}$ indicator that moves relative to the scale to represent a measure of $WOB_{PATIENT}$. The scale may be divided into sectors that generally correspond to different work of breathing levels. The sectors may be visibly discernable from each other (or at least from immediately adjacent sectors).

The elastic-resistive WOB graphic may be divided into a first portion and a second portion, the first portion indicating the elastic WOB component ($WOB_{PATIENT\text{-}ELASTIC}$) and the second portion indicating the resistive WOB component ($WOB_{PATIENT\text{-}RESISTIVE}$). The overall size of the elastic-resistive WOB graphic may remain constant as the relative sizes of the first and second portions dynamically adjust to indicate a measure of the elastic WOB component relative to a measure of the resistive WOB component.

Each work of breathing measure (e.g., $WOB_{TOTAL}$, $WOB_{PATIENT}$, $WOB_{VENTILATOR}$, $WOB_{PATIENT\text{-}ELASTIC}$, and/or $WOB_{PATIENT\text{-}RESISTIVE}$) may be calculated and/or displayed using any suitable units or other parameter. For example, each WOB measure may be calculated and/or displayed as Joules (J), Joules per liter (J/L), Joules per minute (J/min) (i.e., power), or Joules per liter per kilogram (J/L/kg) (i.e., normalized power). Thus, it should be understood that the following discussion of WOB measures displayed in J/L is exemplary only.

FIG. **4** illustrates an example of a WOB graphic **16** *a* on a display device **100**, according to one embodiment of the disclosure. WOB graphic **16** *a* may include a scale **200**, a $WOB_{TOTAL}$ indicator **202** for indicating a measure of the total WOB, a $WOB_{PATIENT}$ indicator **204** for indicating a measure of the patient's WOB, and/or an elastic-resistive WOB indicator **206** for indicating the elastic and resistive WOB components of the patient's WOB. Scale **200** may be divided into a plurality of sectors that may generally correspond to different levels of acceptability, desirability, or safety regarding the patient's breathing. For example, such sectors may include at least one first sector representing a sub-normal work of breathing range, at least one second sector representing a normal work of breathing range, and at least one third sector representing a supra-normal work of breathing range. As another example, such sectors may include at least one first sector representing a sub-normal work of breathing range, at least one second sector representing a normal work of breathing range, at least one third sector representing a supra-normal work of breathing range, and at least one fourth sector representing a cautionary supra-normal work of breathing range.

In the example shown in FIG. **4**, scale **200** may include four sectors, **210**, **212**, **214**, and **216**, which correspond to a sub-normal work of breathing range (sector **210**), a normal work of breathing range (sector **212**), a supra-normal work of breathing range (sector **214**), and a cautionary supra-normal work of breathing range (sector **216**). Sub-normal sector **210** may represent a range in which the patient's WOB may be below an appropriate level for administering a proper respiratory management protocol. Normal sector **212** may represent a range in which the patient's contributed WOB may be within an appropriate level for administering a proper respiratory management protocol. Supra-normal sector **214** may represent a range in which the patient's WOB may be above an appropriate level for administering a proper respiratory management protocol. Cautionary supra-normal sector **216** may represent a range in which the patient's WOB may be at a potentially harmful level. It should be understood that in other embodiments, WOB graphic **16** *a* may include any number and/or type(s) of sectors corresponding to any various conditions.

$WOB_{TOTAL}$ indicator **202** may comprise any pointer or other graphic that may advance and retreat along scale **200** as the $WOB_{TOTAL}$ changes over time (e.g., when a "percent support" setting is adjusted in a PAV ventilation environment). $WOB_{TOTAL}$ indicator **202** may include any suitable label or other identifier. In some embodiments, $WOB_{TOTAL}$ indicator **202** may include a numerical indication of the current $WOB_{TOTAL}$ measure. In other embodiments, no such numerical indication is displayed.

Similarly, $WOB_{PATIENT}$ indicator **204** may comprise any pointer or other graphic that may advance and retreat along scale **200** as the $WOB_{PATIENT}$ changes over time. $WOB_{PATIENT}$ indicator **204** may include any suitable label or other identifier. In some embodiments, $WOB_{PATIENT}$ indicator **204** may include a numerical indication of the current $WOB_{PATIENT}$ measure. In other embodiments, no such numerical indication is displayed.

Elastic-resistive WOB indicator **206** may be divided into a first indicator portion **220** representing a measure of $WOB_{PATIENT\text{-}ELASTIC}$, and a second indicator portion **222** representing a measure of $WOB_{PATIENT\text{-}RESISTIVE}$. The relative sizes of first and second indicator portions **220** and **222** may adjust dynamically as the relative measures of $WOB_{PATIENT\text{-}ELASTIC}$ and $WOB_{PATIENT\text{-}RESISTIVE}$ change over time. In some embodiments (e.g., as such as shown in FIG. **4**), elastic-resistive WOB indicator **206** may be coupled to or otherwise associated with $WOB_{PATIENT}$ indicator **202**, such that elastic-resistive WOB indicator **206** advances and retreats along scale **200** in coordination with $WOB_{PATIENT}$ indicator **202**.

In this embodiment, scale **200** is oriented horizontally and $WOB_{TOTAL}$ indicator **202**, $WOB_{PATIENT}$ indicator **204**, and elastic-resistive WOB indicator **206** move horizontally along scale **200**. In other embodiments, scale **200** may be oriented, and indicators **202**, **204**, and/or **206** may move, in any other direction (e.g., vertically, diagonally, in a stepped manner, or in a curved manner). Indicators **202**, **204**, and/or **206** may be positioned relative to scale **200** in any suitable manner. For example, **202**, **204**, and/or **206** may be positioned on the same side of scale **200** or on opposite sides of scale **200**. As another example, one or more of indicators **202**, **204**, and/or **206** may be partially or fully superimposed over scale **200** and may advance or retreat along or through sectors **210-216** to indicate one or more work of breathing measures. Further, scale **200** and indicators **202**, **204**, and/or **206** may be positioned anywhere on WOB graphic **16** *a*.

In some embodiments, sector transition lines may divide the respective sectors of WOB scale **200**. For example, as shown in FIG. **4**, sector transition lines **230**, **232**, **234**, **236**, and **238** may divide sectors **210-216**. Sector transition lines **230-238** may have any suitable shape and orientation. For example, sector transition lines **230-238** may be shaped to mirror or correspond to the shape or form of one or both ends of elastic-resistive WOB indicator **206**. In other embodiments, scale **200** may not include sector transition lines.

In some embodiments, sectors **210-216** may be visibly discernable from each other, or at least from immediately adjacent sectors. For example, sectors **210-216** may be color-coded, shaded, or differently shaped such that sectors **210-216** may be visibly distinguishable from each other. Such color coding is represented in FIG. **4** by different levels of shading.

In an example embodiment, sector **210** may be color-coded yellow, sector **92** may be color-coded green, sector **94** may be color-coded yellow, and sector **96** may be color-coded

orange, which may be commensurate with good human factors. It should be understood that any coloring may be chosen for each respective sector. Such color-coding may permit the caregiver to quickly and easily determine the location of indicators **202**, **204**, and/or **206** along the scale and/or provide the caregiver a quick indication of the status of the ventilatory support. In other embodiments, one, some or all of sectors **210-216** may be free from color-coding or other types of fill.

Elastic-resistive WOB indicator **206** may have any suitable shape and/or configuration. For example, elastic-resistive WOB indicator **206** may comprise a box, as shown in FIG. **4**, or may take the form of a bar graph, a vertically-oriented line segment, or any other suitable symbol or graphic representation that may advance and retreat along sectors **210-216** to indicate measures of $WOB_{PATIENT\text{-}ELASTIC}$ and/or $WOB_{PATIENT\text{-}RESISTIVE}$. For example, in one embodiment, elastic-resistive WOB indicator **206** comprises a bar or other graphic that expands in length along scale **200** to indicate a measure of $WOB_{PATIENT}$. The bar or other graphic may be divided into indicator portions **220** and **222** that may adjust dynamically to indicate measures of $WOB_{PATIENT\text{-}ELASTIC}$ and $WOB_{PATIENT\text{-}RESISTIVE}$ over time. In some embodiments (e.g., where elastic-resistive WOB indicator **206** is superimposed over scale **200**), the height of elastic-resistive WOB indicator **206** (in the vertical direction as shown in FIG. **4**) may be less than the height of scale **200**, which may increase the visual contrast between elastic-resistive WOB indicator **206** and scale **200**.

In some embodiments, the overall (or exterior) size and/or shape of elastic-resistive WOB indicator **206** remain constant, while the relative sizes of component portions **220** and **222** adjust dynamically. In other embodiments, the overall (or exterior) size and/or shape of elastic-resistive WOB indicator **206** may change over time. For example, in embodiments in which elastic-resistive WOB indicator **206** comprises a bar graph (e.g., extending from the left edge of scale **200**), the horizontal length of elastic-resistive WOB indicator **206** may be dynamic.

In some embodiments, scale **200** may include a set of numerical indices **240** to quantify the range of WOB values for each sector **210-216**. Such values may have any suitable units, e.g., Joules (J), Joules per liter (J/L), Joules per minute (J/min) (i.e., power), or Joules per minute per kilogram (J/min/kg) (i.e., normalized power). The particular values defined by numerical indices **240** (and thus, the ranges of each sector **210-216**) may be determined based on any suitable data, e.g., historical data. In some embodiments, the values defined by numerical indices **240** may be permanent for WOB graphic **16** *a*. In other embodiments, the values defined by numerical indices **240** may be configurable and/or adjustable by an operator. In addition, different numerical indices **240** having different values may be used for different patients, different respiratory management protocols, or for any other varying parameter(s).

One example set of numerical indices **240** is shown in FIG. **4**. In this example, suppose that a normal acceptable range for a patient's WOB ($WOB_{PATIENT}$) is typically 0.3 J/L to 0.7 J/L. Thus, the range from 0 J/L to 0.3 J/L may be deemed subnormal. Thus, unless there are particular reasons for allowing a patient's WOB to fall below 0.3 J/L, a $WOB_{PATIENT}$ reading consistently remaining below 0.3 J/L could signal to the caregiver that the patient's management protocol should be reconsidered. Further, suppose that values falling above 0.70 J/L are generally above an acceptable level. Thus, unless there are particular reasons for allowing a patient's WOB to rise above 0.7 J/L, a $WOB_{PATIENT}$ reading consistently remaining above 0.7 J/L could signal to the caregiver that the patient's management protocol should be reconsidered. Further, suppose that values falling above 1.0 J/L are deemed to be particularly cautionary or potentially harmful. Thus, unless there are particular reasons for allowing a patient's WOB to rise above 1.0 J/L, a $WOB_{PATIENT}$ reading consistently remaining above 1.0 J/L could signal to the caregiver that the patient's management protocol is particularly cautionary or potentially harmful and should thus be reconsidered.

Thus, in this example, the set of numerical indices **240** includes the values 0, 0.3, 0.7, 1.0, and 2.0 positioned proximate the corresponding sector transition lines **230-238**. A graphic representation of the unit of measurement, e.g., Joules/liter (J/L), may be included, as shown in FIG. **4**, or may be omitted. Numerical indices **240** may be otherwise positioned and/or configured to correspond to appropriate sector transitions or other points within sectors **210-216** of WOB graphic **16** *a*.

In some embodiments, WOB graphic **16** *a* may include a WOB units selector **242** (e.g., a button) providing an interface allowing an operator to select from multiple units for which to display WOB measures on WOB graphic **16** *a*. For example, selecting button **242** may open a window allowing the user to select from different units—e.g., Joules (J), Joules per liter (J/L), Joules per minute (J/min), or Joules per minute per kilogram (J/min/kg)—for which WOB measures are displayed in WOB graphic **16** *a*. When an operator selects a particular unit, the values and/or units displayed in numerical indices **240** may be automatically updated as appropriate. In this manner, this operator may select a desired units setting for WOB measures displayed in WOB graphic **16** *a*.

Like scale **200**, elastic-resistive WOB indicator **206** may be configured such that indicator portions **220** and **222** are visibly discernable from each other, such that a caregiver can quickly and easily identify the relative magnitudes of $WOB_{PATIENT\text{-}ELASTIC}$ and $WOB_{PATIENT\text{-}RESISTIVE}$. In some embodiments, indicator portions **220** and **222** are shaded in two different colors (or two different shades of the same basic color). However, it should be understood that indicator portions **220** and **222** may be otherwise colored or shaded, or may not be colored or shaded at all.

Indicator portions **220** and **222** may be divided by a reader **250**, which may dynamically move within elastic-resistive WOB indicator **206** (e.g., to the left or right) to adjust the relative sizes of indicator portions **220** and **222** as the relative magnitude and/or percentage of the resistive and elastic WOB components change over time. In some embodiments, reader **250** may double as, or be otherwise associated with $WOB_{PATIENT}$ indicator **204**. In other embodiments, reader **250** may be distinct from $WOB_{PATIENT}$ indicator **204**. In other embodiments, a leading or trailing line of elastic-resistive WOB indicator **206**, or any other appropriate graphic representation within or associated with elastic-resistive WOB indicator **206**, may serve as $WOB_{PATIENT}$ indicator **204**. For example, the leading end (here, the right-most boundary or indicator portion **222**) may serve as $WOB_{PATIENT}$ indicator **204**.

In other embodiments, elastic-resistive WOB indicator **206** may simply comprise a line or other suitable indicating means, and the patient's resistive and/or elastic WOB components may be graphically displayed separately, as numerical values of an appropriate unit of measure, or in any other suitable manner.

In some embodiments of the present disclosure, the caregiver may be able to easily identify the relative percentages of the patient's resistive work and elastic work from indicator portions **220** and **222**, respectively, of elastic-resistive WOB indicator **206**. By dividing elastic-resistive WOB indicator **206** into resistive and elastic WOB components **220** and **222**, a caregiver may be able to easily determine whether a patient

is exerting too much or too little resistive or elastic work, which in turn may assist the caregiver in diagnosing the patient's condition and/or adjusting the ventilation strategy.

In some embodiments, WOB graphic **16** *a* may include one or more display legends that may include any desired graphical representations to assist the caregiver in better understanding WOB graphic **16** *a*. For example, as shown in FIG. **4**, a display legend **260** may indicate that indicator portions **220** and **222** of elastic-resistive WOB indicator **206** represent the elastic WOB component (illustrated as "$WOB_E$") and the resistive WOB component (illustrated as "$WOB_R$"), respectively, of the patient's WOB. In other embodiments, symbols or legends indicating that indicator portions **220** and **222** represent the elastic and resistive WOB components may be located in or adjacent to indicator portions **220** and **222** (such as shown in the embodiment of FIG. **6**, for example). Similarly, display legend **260** or another display legend may explain the color-coding of sectors **210-216** of scale **200**.

FIG. **5** illustrates another example of a WOB graphic **16** *b* on a display device **100**, according to one embodiment of the disclosure. WOB graphic **16** *b* may be similar to WOB graphic **16** *a* shown in FIG. **4** and discussed above, but may additionally include a $WOB_{VENTILATOR}$ indicator **270** that indicates a measure of the ventilator's WOB. $WOB_{VENTILATOR}$ indicator **270** may comprise any pointer or other graphic that may advance and retreat along scale **200** as the $WOB_{VENTILATOR}$ changes over time. $WOB_{VENTILATOR}$ indicator **270** may include any suitable label or other identifier. In some embodiments, $WOB_{VENTILATOR}$ indicator **270** may include a numerical indication of the current $WOB_{VENTILATOR}$ measure. In other embodiments, no such numerical indication is displayed.

FIG. **6** illustrates another example of a WOB graphic **16***c* on a display device **100**, according to another embodiment of the disclosure. WOB graphic **16***c* may include a scale **300**, a $WOB_{TOTAL}$ indicator **302** for indicating a measure of the total WOB, a $WOB_{PATIENT}$ indicator **304** for indicating a measure of the patient's WOB, and/or an elastic-resistive WOB indicator **306** for indicating the elastic and resistive WOB components of the patient's WOB.

Scale **300** and indicators **302-306** may be analogous to scale **200** and indicators **202-206** shown in FIG. **4**. Scale **300** may extend in an arc, and may be divided into sections **310-316**, which may be similar to sections **210-216** discussed above. $WOB_{TOTAL}$ indicator **302** may comprise a pointer that rotates relative to curved scale **300** to indicate a measure of the total WOB. Similarly, $WOB_{PATIENT}$ indicator **304** may comprise a pointer that rotates relative to curved scale **300** to indicate a measure of the patient's WOB.

Elastic-resistive WOB indicator **306** may be divided into indicator portions **320** and **322**, which may indicate the elastic and resistive WOB components of the patient's WOB, e.g., as discussed above regarding indicator portions **220** and **222** of elastic-resistive WOB indicator **206**. The relative sizes (e.g., the length and/or width) of indicator portions **320** and **322** may dynamically change to indicate the current relative measures of elastic and resistive WOB components, e.g., as discussed above regarding elastic-resistive WOB indicator **206**. However, unlike elastic-resistive WOB indicator **206**, elastic-resistive WOB indicator **306** may remain stationary (rather than moving along scale **300**). In addition, in some embodiments, an indication that indicator portions **320** and **322** represent the elastic and resistive WOB components is located in or adjacent to indicator portions **320** and **322**. For example, as shown in FIG. **6**, the letters "E" and "R" may be displayed in indicator portions **320** and **322** to indicate that that indicator portions **320** and **322** represent the elastic and resistive WOB components, respectively. In other embodiments, WOB graphic **16***c* may include one or more display legends to provide such information, e.g., as discussed above regarding display legend **260**.

FIG. **7** illustrates another example of a WOB graphic **16***d* on a display device **100**, according to another embodiment of the disclosure. WOB graphic **16***d* may include a scale **400**, a $WOB_{TOTAL}$ indicator **402** for indicating a measure of the total WOB, a $WOB_{PATIENT}$ indicator **404** for indicating a measure of the patient's WOB, and/or an elastic-resistive WOB indicator **406** for indicating the elastic and resistive WOB components of the patient's WOB. Scale **400** and indicators **402-406** may be analogous to scale **300** and indicators **302-306** shown in FIG. **6**. For example, scale **400** may extend in an arc, and may be divided into sections **410-416**. WOB TOTAL indicator **402** may move in an arced path along an inner perimeter of scale **400**. In other embodiments, $WOB_{TOTAL}$ indicator **402** may move along an outer perimeter of scale **400**. $WOB_{PATIENT}$ indicator **404** may move in an arced path along an outer scale **400**, and may be coupled to elastic-resistive WOB indicator **406** such that elastic-resistive WOB indicator **406** moves along with $WOB_{PATIENT}$ indicator **404**. In other embodiments, elastic-resistive WOB indicator **406** and/or $WOB_{PATIENT}$ indicator **404** may move along an inner perimeter of scale **400**.

Elastic-resistive WOB indicator **406** may be divided into indicator portions **420** and **422**, which may indicate the elastic and resistive WOB components of the patient's WOB. The relative sizes of indicator portions **420** and **422** may dynamically change to indicate the current relative measures of elastic and resistive WOB components, e.g., as discussed above regarding elastic-resistive WOB indicator **206**. In addition, in some embodiments, an indication (e.g., the letters "E" and "R") that indicator portions **420** and **422** represent the elastic and resistive WOB components may be located in or adjacent to indicator portions **420** and **422**, such as discussed above regarding FIG. **6**.

FIG. **8** illustrates another example of a WOB graphic **16***e* on a display device **100**, according to another embodiment of the disclosure. WOB graphic **16***e* may include a scale **500**, a $WOB_{TOTAL}$ indicator **502** for indicating a measure of the total WOB, a $WOB_{PATIENT}$ indicator **504** for indicating a measure of the patient's WOB, and/or an elastic-resistive WOB indicator **506** for indicating the elastic and resistive WOB components of the patient's WOB. Scale **500** and indicators **502-506** may be analogous to scale **200** and indicators **202-206** shown in FIG. **4**. Scale **500** may extend in an elliptical or other curved shape, and may be divided into sections **510-516**. $WOB_{TOTAL}$ indicator **502** may move in a curved path along an outer perimeter of scale **500**. In other embodiments, $WOB_{TOTAL}$ indicator **502** may move along an inner perimeter of scale **500**. $WOB_{PATIENT}$ indicator **504** may move in a curved path along an inner scale **500**. In other embodiments, $WOB_{PATIENT}$ indicator **504** may move along an outer perimeter of scale **500**.

Elastic-resistive WOB indicator **506** may be divided into indicator portions **520** and **522**, which may indicate the elastic and resistive WOB components of the patient's WOB. The relative sizes of indicator portions **520** and **522** may dynamically change to indicate the current relative measures of elastic and resistive WOB components. Like elastic-resistive WOB indicator **306** shown in FIG. **6**, elastic-resistive WOB indicator **506** may remain stationary (rather than moving along scale **500**). As discussed above, an indication (e.g., the letters "E" and "R") that indicator portions **520** and **522** represent the elastic and resistive WOB components may be located in or adjacent to indicator portions **520** and **522**.

FIG. **9** illustrates another example of a WOB graphic **16***f* on a display device **100**, according to another embodiment of the disclosure. WOB graphic **16***f* may include one or more scales for indicating the patient's WOB ($WOB_{PATIENT}$), the ventilator's WOB ($WOB_{VENTILATOR}$), and/or the total WOB ($WOB_{TOTAL}$). For example, as shown in FIG. **9**, WOB graphic **16***f* may include (a) a first scale **600***a* for indicating the patient's WOB ($WOB_{PATIENT}$) and/or the elastic and resistive WOB components of $WOB_{PATIENT}$, and (b) a second scale **600***b* for indicating the ventilator's WOB ($WOB_{VENTILATOR}$). In another embodiment, WOB graphic **16***f* may include a third scale for indicating the total WOB ($WOB_{TOTAL}$). In other embodiments, WOB graphic **16***f* may include any one, two or all three of such scales indicating $WOB_{PATIENT}$, $WOB_{VENTILATOR}$, and/or $WOB_{TOTAL}$.

Regarding scale **600***a* shown in FIG. **9**, a $WOB_{PATIENT}$ indicator **604** in the form of a bar may advance and retreat along scale **600***a* to indicate a measure of the patient's WOB, $WOB_{PATIENT}$. $WOB_{PATIENT}$ indicator **604** may be divided into indicator portions **620** and **622**, which may indicate the elastic and resistive WOB components of the patient's WOB, respectively. The sizes of indicator portions **620** and **622** may dynamically change to indicate the current relative measures of elastic and resistive WOB components. An indication (e.g., the letters "E" and "R") that indicator portions **620** and **622** represent the elastic and resistive WOB components may be located in or adjacent to indicator portions **620** and **622**. Alternatively, WOB graphic **16***f* may include a legend (e.g., as discussed above with respect to FIG. **4**) to indicate that portions **620** and **622** represent the elastic and resistive WOB components of the patient's WOB. Indicator portions **620** and **622** may be color-coded or otherwise visually distinct, e.g., as described above. Scale **600***a* may include a set of numerical indices (e.g., similar to numerical indices **240** shown in FIG. **4**) to quantify ranges of WOB values for pre-determined sectors of scale **600***a* (e.g., 0 to 0.3, 0.3 to 0.7, 0.7 to 1.0, and 1.0 to 2.0).

Regarding scale **600***b*, a $WOB_{VENTILATOR}$ indicator **624** in the form of a bar may advance and retreat along scale **600***b* to indicate a measure of the ventilator's WOB, $WOB_{VENTILATOR}$. $WOB_{VENTILATOR}$ indicator **624** may be color-coded or otherwise visually distinct from indicator portions **620** and **622** of $WOB_{PATIENT}$ indicator **604**. In other embodiments, WOB graphic **16***f* may not include scale **600***b* or $WOB_{VENTILATOR}$ indicator **624**. Like scale **600***a*, scale **600***b* may include a set of numerical indices to quantify ranges of WOB values for pre-determined sectors of scale **600***b*. In other embodiments, scales **600***a* and **600***b* may share a common set or numerical indices, or may not include numerical indices.

Although the disclosed embodiments have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the disclosure as illustrated by the following claims.

Those skilled in the art will recognize that the methods and systems of the present disclosure may be implemented in many manners and as such are not to be limited by the foregoing exemplary embodiments and examples. In other words, functional elements being performed by a single or multiple components, in various combinations of hardware and software or firmware, and individual functions, can be distributed among software applications at either the client or server level or both. In this regard, any number of the features of the different embodiments described herein may be combined into single or multiple embodiments, and alternate embodiments having fewer than or more than all of the features herein described are possible. Functionality may also be, in whole or in part, distributed among multiple components, in manners now known or to become known. Thus, myriad software/hardware/firmware combinations are possible in achieving the functions, features, interfaces and preferences described herein. Moreover, the scope of the present disclosure covers conventionally known manners for carrying out the described features and functions and interfaces, and those variations and modifications that may be made to the hardware or software or firmware components described herein as would be understood by those skilled in the art now and hereafter.

While various embodiments have been described, various changes and modifications may be made which are well within the scope of the present disclosure. Numerous other changes may be made which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the disclosure and as defined in the claims.

What is claimed is:

**1**. A breathing support system, comprising:

a breathing support device configured to deliver gas to a patient;

a software-generated graphic indicating one or more measures regarding the patient's work of breathing;

a display device associated with the breathing support device, the display device configured to display the software-generated graphic,

wherein the software-generated graphic includes:

a scale in a form of a bar with a single axis representing a range of work of breathing values; and

one or more work of breathing indicators that move relative to the scale.

**2**. The system according to claim **1**, further comprising a work of breathing calculation module configured to receive data from one or more sensors and calculate the one or more measures using one or more work of breathing algorithms.

**3**. The system according to claim **2**, wherein the data received by the work of breathing calculation module comprises data regarding delivery of gas to the patient, including at least one of pressure and flow of gas delivered to the patient.

**4**. The system according to claim **2**, wherein the work of breathing calculation module is configured to receive data from one or more sensors associated with an artificial airway inserted in the patient.

**5**. The system according to claim **1**, further comprising:

one or more sensors configured to obtain data regarding the patient's breathing;

a memory device storing one or more work of breathing algorithms; and

a processor communicatively coupled to the one or more sensors and the memory device and configured to determine the one or more measures regarding the patient's work of breathing based at least on data obtained by the one or more sensors and the one or more work of breathing algorithms.

**6**. The system according to claim **5**, wherein the one or more sensors are associated with an artificial airway inserted in the patient.

**7**. The system according to claim **5**, wherein the one or more sensors are not associated with an artificial airway inserted in the patient.

**8**. The system according to claim **1**, wherein the display device is at least partially integrated with the breathing support device.

**9**. The system according to claim **1**, wherein the display device is physically separate from the breathing support device.

10. The system according to claim 1, wherein the software-generated graphic includes:

a total work of breathing indicator indicating a measure of the patient's total work of breathing, the total work of breathing comprising a patient work of breathing component and a device work of breathing component, the patient work of breathing component comprising the portion of the total work of breathing provided by the patient and the device work of breathing component comprising the portion of the total work of breathing provided by the breathing support device.

11. The system according to claim 1, wherein the software-generated graphic further includes an indication of an elastic work of breathing component relative to a resistive work of breathing component.

12. The display according to claim 1, wherein the one or more measures comprise one or more estimated measures regarding the patient's work of breathing.

13. The system according to claim 1, wherein the software-generated graphic includes:

an elastic-resistive indicator indicating a measure of the elastic work of breathing component relative to a measure of the resistive work of breathing component.

14. The system according to claim 1, wherein the software-generated graphic includes:

an elastic-resistive graphic including a first portion and a second portion, the first portion indicating a measure of an elastic work of breathing component and the second portion indicating a measure of a resistive work of breathing component; and

wherein relative sizes of the first and second portions of the elastic-resistive graphic dynamically adjust to indicate the measure of the elastic work of breathing component relative to the measure of the resistive work of breathing component.

15. The system according to claim 14, wherein the size of the elastic-resistive graphic remains constant as the relative sizes of the first and second portions dynamically adjust.

16. The system according to claim 1, wherein the work of breathing value is Joules per minute (J/min) or Joules per Liter (J/L).

17. A breathing support system, comprising:

a breathing support device configured to deliver gas to a patient;

a software-generated graphic indicating one or more measures regarding the patient's work of breathing;

a display device associated with the breathing support device, the display device configured to display the software-generated graphic, and

wherein the software-generated graphic includes:

an elastic-resistive graphic including a first portion and a second portion, the first portion indicating a measure of an elastic work of breathing component and the second portion indicating a measure of a resistive work of breathing component; and

wherein relative sizes of the first and second portions of the elastic-resistive graphic dynamically adjust on a bar to indicate the measure of the elastic work of breathing component relative to the measure of the resistive work of breathing component.

18. The system according to claim 17, wherein the size of the elastic-resistive graphic remains constant as the relative sizes of the first and second portions dynamically adjust.

19. The system according to claim 17, further comprising a work of breathing calculation module configured to receive data from one or more sensors and calculate the one or more measures regarding the patient's work of breathing using one or more work of breathing algorithms.

20. The system according to claim 19, wherein the data received by the work of breathing calculation module comprises data regarding delivery of gas to the patient, including at least one of pressure and flow of gas delivered to the patient.

21. The system according to claim 17, further comprising:

one or more sensors configured to obtain data regarding the patient's breathing;

a memory device storing one or more work of breathing algorithms; and

a processor communicatively coupled to the one or more sensors and the memory device and configured to determine the one or more measures based at least on data obtained by the one or more sensors and the one or more work of breathing algorithms.

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